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CALIBRATION OF A METAL GAS X-RAY TUBE

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Since the copper target metal gas x-ray tube described by Kersten (5) has been used in numerous biological and biochemical experiments, (1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 20, 21) it was thought advisable to calibrate the energy output of the tube in r-units. Because of its wide application and because no calibration curves for a tube of this type have been published the data was considered of sufficient interest to warrant this paper.

The r-unit output of the tube was determined by means of the standard ionization chamber for soft x-rays described by Taylor (19). Although with this chamber it is usual to collect and measure an electrical charge, the authors elected to measure a charge in motion as an electrical current with the aid of a modification of the feed-back microammeter described by Roberts (15). This method gives an instantaneous indication of the energy output whereas measurements involving an electrometer or any other integrating instrument read only the average output over a period of time and gives its indication only at the end of the period. Such results are averages and are more reproducible than instantaneous readings. For this reason and because with this metal x-ray tube and probably with all other similar tubes it was found that the output was not always the same for a fixed current and voltage input, the results are reproducible only to the extent of plus or minus 10 percent.

The feed-back microammeter may be built by any radio mechanic from parts which may be obtained at a radio supply house for about $35. The ionization chamber may be built by a machinist from brass, Bakelite, and amber insulation costing less than $20. No special skill is required in using the equipment. An added feature of the apparatus is that the meter on which the r-units are indicated may be connected to the rest of the microammeter through a lamp cord of any length so that instantaneous readings of the r-units may be read at the control panel.

The Taylor chamber was used in these measurements because it had been tested and found to be free of errors due to distortion of the electrostatic field in the region of the collector plate. It also has provision for making air absorption corrections which accounts for a large part of its volume. The readings given here are reproducible to within about 10 percent and therefore do not include air absorption corrections. For this reason a smaller chamber might have been used.

The feed-back microammeter and one thousand volt D.C. supply for the ionization chamber were built in a box mounted on one side of the ionization chamber as shown in Fig. 1. The lower appendage shown in the figure provides space for connections between the two units, for the 12J7-GT tube which is mounted in a horizontal position, and for the range selector switch, S-2.

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Fig. 2 shows the circuit diagram of the amplifier. The power is supplied by the 50Y6-GT tube connected in a doubler circuit which permits grounding the negative side of the rectifier output. With such a circuit it is necessary to have the A.C. power line connected in the correct manner so that a pilot light is provided as an indicator. Incorrect polarity on the power cord will cause the light to burn when the case of the microammeter is grounded. If the lamp lights the plug should be reversed immediately in its receptacle. The selector switch S-2 is provided so that a large range of r-units may be measured on the same instrument. If R-1 is made 60 megohms, a full-scale reading on the 0-30 microammeter will be 3 r-units per second or 180 per minute. If R-1 is 30 megohms the full-scale reading will be 6 r-units per second or 360 per minute and so on. This ratio will hold for values of R-1 in the range of from 0.1 to 100 megohms.

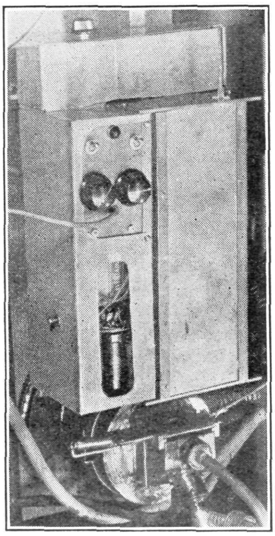

FIGURE 1

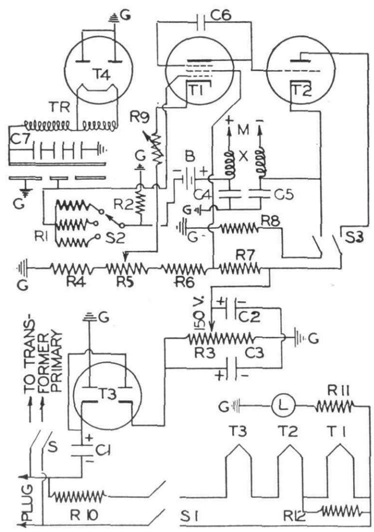

FIGURE 2

FIG. 1. Photograph showing the ionization chamber and combined feedback amplifier and power supply in position below the x-ray tube window.

FIG. 2. Schematic diagram of the amplifier and power supply. T-1, 12J7-GT; T-2, 12SF-5-GT; T-3, 50Y6-GT; T-4, 5W4; TR, Power transformer, 700 volts; 5 volts, 2 Amp.; R-1, see text; R-2, 2000 ohm precision non-inductive resistor; R-3, 25000 ohm 10 watt Dividohm; R-4, 500 ohm, ½ watt; R-5, 1000 ohm potentiometer; R-6, 20000 ohm, ½ watt; R-7, 120000 ohm, ½ watt; R-8, 50000 ohm, ½ watt; R-9, 1000 ohm potentiometer; R-10, 320 ohm Cordohm; R-11, 200 ohm, 10 watt; R-12, 150 ohm, ½ watt; C-1, 16 mfd. 250 volt; C-2, 16 mfd. 250 volt; C-3, 16 mfd. 400 volt; C-4, .01 mfd. mica; C-5, .01 mfd. mica; C-6, .01 mfd. mica; C-7, three 8 mfd. condensers in series; X, 80 millihenry chokes; M, 0-30 microammeter; B, 22.5 volt B-battery; S, DPST toggle switch; S-1, DPST toggle switch; S-2, 3-position selector switch; S-3, DPST toggle switch, L, 2.5 volt, ½ amp. pilot lamp; G, grounded to case.

Best results will be obtained with this instrument if it is operated from a stabilized A.C. source. If the x-ray apparatus is equipped with a magnetic stabilizer which will supply 115 volts with one of the lines grounded, the amplifier may be connected to it. Otherwise it may be supplied through a separate 25 watt stabilizer. The fact that the zero setting, which is controlled by the potentiometer and rheostat R-5 and R-9, may drift very slowly while readings are being taken is of no consequence since all measurements should be made as a difference of two readings; one with the x-rays entering the chamber and one with the x-rays cut off.

We consider one bit of information derived from these tests to be of considerable interest. As mentioned, it was found that the energy output for a gas x-ray tube of this type operated at a constant voltage and current is not constant. Two

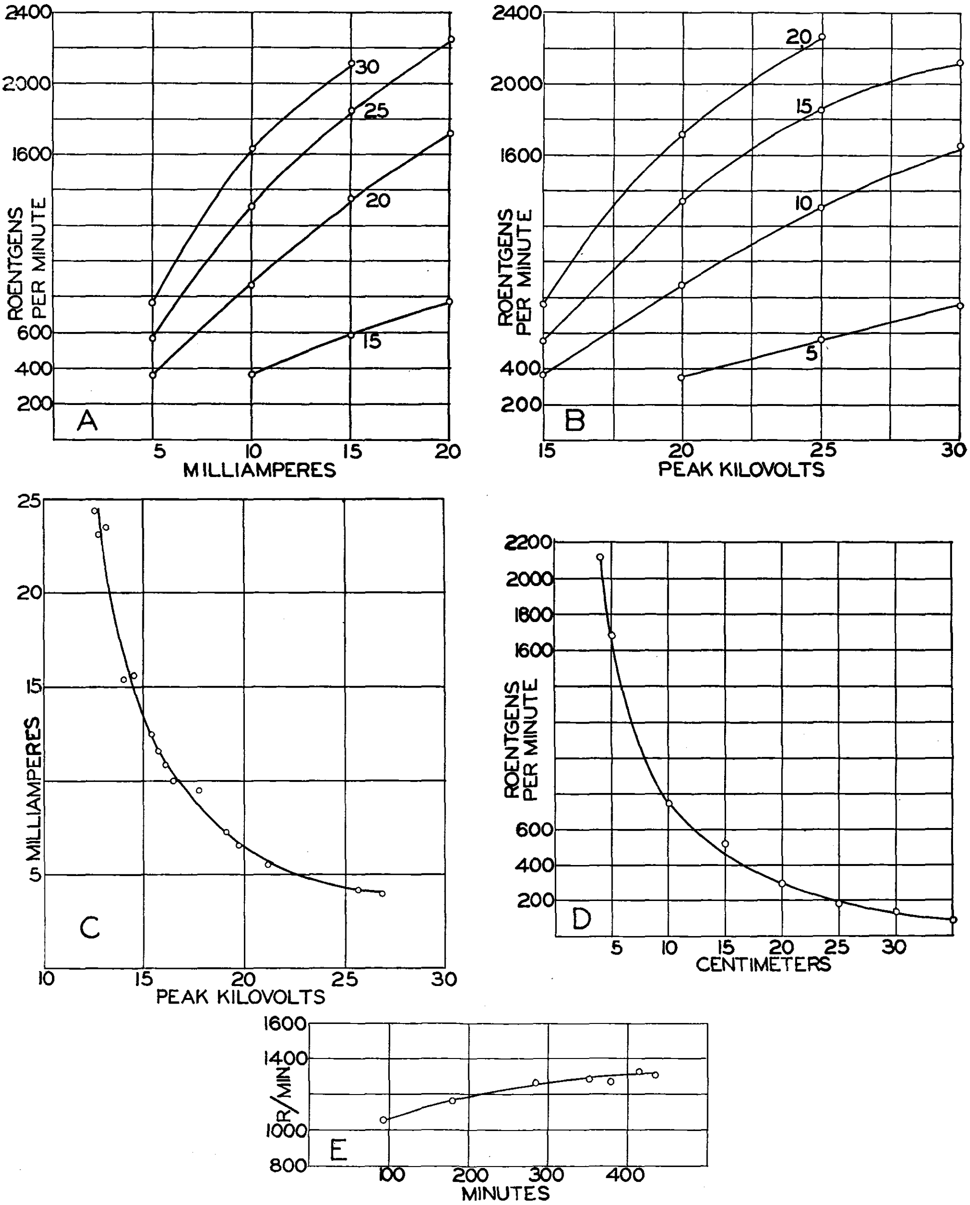

FIG. 3. A, Roentgens per minute as a function of tube current in millamperes, 5 cm. from the tube window. The numbers next to the curves indicate peak kilovolts. B, Roentgens per minute as a function of peak kilovolts, 5 cm. from the tube window. The numbers next to the curves indicate tube current in milliamperes. C, Tube current as a function of peak kilovolts for a constant output of 635 r per minute, 5 cm. from the tube window. D, Roentgens per minute as a function of distance from the tube window when the tube was operated at 30 peak kilovolts, 10 millamperes. E, Roentgens per minute as a function of time elapsed after initial evacuation. 20 peak kilovolts, 15 milliamperes.

types of change in output at constant input have been observed. The first of these is a gradual increase in output as the tube is used. A test was made to illustrate the phenomenon. The tube was opened to atmospheric pressure by removing the Cellophane and aluminum window. New windows of the same material and of the same thickness were installed and the tube pumped until sufficient vacuum was established to take readings at 20 kv. and 15 ma. Readings were taken at intervals for several hours. The results were plotted in Fig. 3E. Therefore, before readings for the other figures were taken the tube was operated for a sufficient time to insure their constancy.

The second change in output was noted to occur occasionally and is of the following nature. For any given voltage and current in the ranges shown in Fig. 3A-D the r-unit output may decrease to as little as one-third of that given in those figures. As yet the cause for this has not been established but it can be pointed out that in this design the anode almost surrounds the cathode and therefore all the electrons indicated by the milliammeter do not need to strike the anode in the usual focal spot position above the window. The data given in the figures therefore represent the maximum output, which is also the usual output, of the tube.

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